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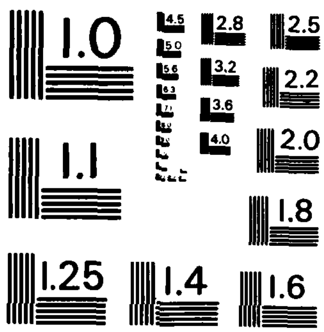

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MELBOURNE, VICTORIA

AD-A160 736

Structures Technical Memorandum 415

THE TEST LOADS SEQUENCES APPLIED TO THE CT4

FULL SCALE FATIGUE TEST

by

Leonard R. GRATZER

Approved for Public Release

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SUMMARY

This document presents an outline of the derivation of the test load sequences applied to the CT4 full scale fatigue test.

POSTAL ADDRESS: Director, Aeronautical Research Laboratories,
P.O. Box 4331, Melbourne, Victoria, 3001, Australia.

CONTENTS

1. INTRODUCTION

As part of the evaluation of the fatigue life of the CT4 airtrainer operated by the RAAF and RNZAF a full scale fatigue test was carried out during 1983-1984.

This document describes the various load spectra applied to the test article and outlines the derivation of jack loads used.

This test was required to verify lives deduced from two CT4 spar boom tests (Ref. 1) for the wing centreline joint and root rib. A fuller treatment is in preparation.

2. REQUIREMENTS

The original test requirement was to produce a sequence of jack loads to be applied to the wings, undercarriage, horizontal tailplane and vertical fin of the CT4 fatigue test article. The loads were to be representative of Point Cook average squadron usage as defined by fatigue meter records (form 363) up to June 1982. For the 1983-4 fatigue test, the sequence of jack loads was determined by wing and undercarriage loads. Simultaneous empennage loads were applied to the test article during a later test in 1985. For that test, wing loads were set to the level flight value.

3. APPROACH FOR COMMON LOADS

Loads were required to represent manoeuvre, gust and ground loads. To supply representative data, the main flight trials (ARDU Test Schedule 1649) began in April 1980. The trials were flown by four ARDU pilots on aircraft A19-031. The first two pilots flew six missions each, representing both student and instructor flying under full fuel conditions, to represent a complete flight training syllabus. The flights were then repeated by the third and fourth pilots with half fuel.

Flight manoeuvre loads were derived from these 24 flights.

Gust loads were derived by modifying the data recorded on one flight of the test aircraft flown on 29 April 1980, to match the gust spectrum provided by Sherman and Ford (Refs. 2 and 3) and shown in Table 1.

Ground loads were obtained from take-off, touch-and-go and taxi loads recorded on 8 May, 9 and 19 June 1980. These included normal and heavy landings on grass and bitumen.

A complete summary of all flights used in the production of the test sequence is shown in Table 2.

4. TURNING POINT SELECTION - CRITERIA AND METHOD

Data reduction of flight trials data was accomplished in two stages. In the first, four channels were selected as shown in Table 3. During computer processing, when a turning point that exceeded the discriminator #1 occurred on any one of the four indicator channels, the strain data from ALL channels were converted to engineering units #2 and written to a disk file.

4.1 Flight Loads

In the second stage of data reduction, the strain data were converted into jack loads and then small load ranges were removed using the jack load primary filter levels shown in Table 3.

Methods used to estimate jack loads from strain measurements are given in an appendix.

4.2 Ground Loads

Bending moments and axial loads in the undercarriage legs were evaluated using the calibration results in Ref. 4. When the jack loads calculated from these data were applied to the fatigue test article during the preliminary load sequence the strains were found to be approximately 20% lower than those measured during the flight trials. This was attributed to not applying varying vertical and side loads concurrently during the calibration causing incorrect bending moment and axial load to strain relationships to be developed.

A further calibration was performed during August 1983 in which moment arms were measured to each gauge position. Bending moments and axial load to strain relationships were evaluated, Table 4 shows the results of the calibration, and Table 5 shows the calculated vertical and side loads and compares these with the measured values.

5. TURNING POINT SELECTION FOR LOAD TAPE

To reduce the total number of turning points on the load tape, the primary jack load sequence was further filtered using a discriminator of 350 lb. (1557 N, = 0.5g), on the wing jack. Only empennage loads that occurred at the same time as the selected wing loads were left in the load tape.

#1 The discriminator is the range that must be exceeded before a valid turning point is registered.

#2 Ref. 1 contains conversion factors.

6. DESCRIPTION OF THE TEST LOAD SEQUENCE (TLS)

The test load sequence to 25500 simulated service hours (648 programs) consisted of four distinct sets of loads. This was followed by a severe spectrum to failure (Table 6).

6.1 Preliminary Sequence

To enable the test to begin in June 1983, a simple spectrum was applied initially. It was designated PRELIM and coded SPECTRUM 100. It contained no gust or rare loads, nor were any heavy landings represented. It was applied for the first 36 programs of the test. By comparing these 36 programs with 1200 missions of Point cook fatigue meter data, it can be seen that a reasonable agreement was achieved.

Exceedance Levels (g)

-2.5	-1.5	-0.5	2.5	3.5	4.5	6.0	
0	252	864	9972	2736	288	0	Spect.100 x36
1.9	75.9	1733.2	10230.5	2739.7	335.5	0.3	Pt.Cook x 1200s

6.2 Rare Loads

The second spectrum (200) designated PENULT had the gust flights added. This added to each program 51 repetitions of the special gust flight applied in 3 groups of 13 and one group of 12. Some of the wing loads were manually edited to achieve the closest possible agreement to the required Point Cook spectrum. A new flight (018) was included to provide some rare loads. (Table 7).

To achieve the required spectra, each turning point in the sequence had a modulus associated with it. This modulus specifies how many programs must be completed before a particular turning point is applied.

In most cases the modulus is one, i.e. the turning point is applied every program. For the 6g load, the modulus is 144 meaning that this load is applied once every 144 programs. SPECTRUM 200 was applied for two programs (37 and 38). Further testing revealed that the gust spectrum was low at the 1.5g level. This was corrected and the spectrum now coded 210. The designation PENULT still applied. SPECTRUM 210 was applied for 89 programs (39 to 127).

6.3 Major Test Sequence

A new spectrum was required when the undercarriage loads were corrected following a new calibration. The wing loads were unchanged. The new spectrum was designated PEN2 and coded 220. This spectrum completed 521 programs (128 to 648) to bring the simulated test time to 25463 hours, as required by the CT4 Fatigue Test Specification.

7. FURTHER TESTING

It was found by performing damage calculations that the test time to major structural failure would be excessive. Due to financial constraints the test time had to be shortened to enable a satisfactory conclusion to be reached.

A new severe spectrum (230) was created and designated PEN5. All peaks less than 3000 lb (13.3kN) were increased by 668 lb (2.97kN, 1g)and all other peaks were increased by 334 lb (1.49kN, 0.5g). The maximum load was limited to 4008 lb (17.8kN, 6g). All troughs had 334 lb subtracted from them to a minimum of -1670 lb (-7.4kN, -2.5g). All gust flights were removed from this spectrum. This spectrum was applied until a major failure occurred at program 798 on the port wing spar. The equivalent life was approximately 50,000 hours. Table 8 shows the complete load spectrum applied to the test aircraft.

8. STRAIN COMPARISONS

To check that valid wing loads were being applied to the fatigue test article, a comparison of strains was undertaken.

Gauges 9BE and 10BE at wing station 42 inches were chosen as representative gauges. it can be seen from Table 9 that the fatigue test strains compare favourably with the Flight Trials strains at the three load levels chosen. Also shown in this table are the same measurements repeated as the test progressed to the last high load calibration prior to the spectrum change at program 648.

9. CONCLUSION

A CT4 Airtrainer has been fatigue tested to approximately 50,000 simulated test hours. A number of jack load sequences were applied to the fatigue test article. The methods used in their derivation have been outlined.

REFERENCES

1.	D.G. Ford	CT4-A Spar Boom Fatigue Tests - Results and Implications. ARL-STRUCT-REPORT 379, October, 1979.
2.	D.J. Sherman	The Cumulative Exceedance Distribution of Accelerations due to Turbulence Encountered by a CT4-A Airtrainer. ARL-STRUCT-TECH-MEMO 364, August 1983.
3.	D.G. Ford	Estimation of the Average Flight Profile of the CT4-A Airtrainer. ARL-STRUCT-TECH-MEMO December, 1984.
4.	V. Romeo	Calibration of a Strain Gauged CT4-A Undercarriage. ARL-STRUCT-TECH-MEMO 308 August, 1980.
5.	Aero Engine Services *New Zealand*	Report No. CT4-4 Airtrainer Component Loading - Wings, October 1973.
6.	R.P. Carey	Ground Calibration of a Strain Gauged CT4-A Aircraft (1980). ARL-STRUCT-TECH-MEMO 349 October, 1982.

Table 1 - Gust Spectrum

Exceedance Level (g)				Detail
0.5	0.75	1.25	1.5	
1.91	30	63.4	4	Exceedances/Hour
75.1	1178.8	2487.3	157.2	Exceedances/Prog.

Table 2 - Flight Trials Summary

FLIGHT	DATE	DESCRIPTION
12	29/4/80	FULL FUEL MISSION 1
13	30/4/80	FULL FUEL MISSION 2
14	1/5/80	FULL FUEL MISSION 3
15	2/5/80	FULL FUEL MISSION 4
16	5/5/80	FULL FUEL MISSION 5
17	5/5/80	FULL FUEL MISSION 6
18	7/5/80	HIGH LEVEL FULL FUEL ENVELOPE FLIGHT
20	8/5/80	FULL FUEL MISSION 8 (U/C) FLIGHT
23	4/6/80	FULL FUEL MISSION 1
24	4/6/80	FULL FUEL MISSION 3
25	5/6/80	FULL FUEL MISSION 2
26	5/6/80	FULL FUEL MISSION 4
27	6/6/80	FULL FUEL MISSION 6
28	6/6/80	FULL FUEL MISSION 5
29	9/6/80	FULL FUEL MISSION 8 (U/C)
30	10/6/80	HALF FUEL MISSION 1
31	10/6/80	HALF FUEL MISSION 2
32	11/6/80	HALF FUEL MISSION 3
33	12/6/80	HALF FUEL MISSION 4
34	12/6/80	HALF FUEL MISSION 5
36	19/6/80	HALF FUEL MISSION 8 (U/C)
37	20/6/80	HALF FUEL MISSION 6
40	17/7/80	HALF FUEL MISSION 1
41	18/7/80	HALF FUEL MISSION 2
42	18/7/80	HALF FUEL MISSION 3
43	21/7/80	HALF FUEL MISSION 4
44	22/7/80	HALF FUEL MISSION 5
45	22/7/80	HALF FUEL MISSION 6

Table 3 - Indicators and Discriminators used in Jackload Derivation.

Transducers	Indicator Channels	Discriminator Computer Units	Discriminator Engineering Units
nz	1	40	0.2g
SG10	24	25	36
SG33	38	50	38.7
SG38	42	50	36.3

Indicator Channels and Discriminators Used in initial Data Compression

↓

Jack position	Discriminator
Wing	134 lb / 596 N
Tailplane	62 lb / 276 N
Fin	65 lb / 289 N

Primary Filtering of Jackloads

↓

Jack Position	Discriminator
Wing	350 lb / 1557 N

Secondary Filtering of Jackloads

Table 4 - CT4 Calibration and Moment Arm Measurements for Undercarriage Loading

Total Vertical Load 2V(lb)	Side Load S (lb)	SG44T με	SG46BE με	STARBOARD RHO-V (inch)	STARBOARD RHO-S (inch)	PORT RHO-V (inch)	PORT RHO-S (inch)
107.0	-480.0	-3.0	1083.0	22.27	26.36	21.89	27.08
60.0	-290.0	-3.0	674.0	22.03	26.80	21.74	27.60
67.0	-91.0	-2.0	239.0	21.84	27.43	21.62	28.18
85.0	8.0	-1.0	16.0	21.64	27.80	21.42	28.44
127.0	112.0	-1.0	-212.0	21.48	27.99	21.19	28.80
50.0	313.0	0.0	-678.0	21.13	28.53	20.79	29.20
575.0	-480.0	0.0	1433.0	22.43	25.78	22.21	26.79
490.0	-297.0	0.0	1044.0	22.11	26.27	22.01	27.11
514.0	-96.0	0.0	613.0	21.99	26.93	21.70	27.72
506.0	2.0	1.0	393.0	21.91	27.25	21.50	28.00
516.0	98.0	1.0	164.0	21.68	27.55	21.38	28.28
518.0	323.0	3.0	-306.0	21.33	28.13	21.03	28.85
516.0	524.0	2.0	-798.0	20.89	28.72	20.60	29.37
1012.0	-502.0	3.0	1865.0	22.70	25.17	22.41	25.99
970.0	-288.0	3.0	1495.0	22.66	25.65	22.05	26.51
1017.0	-99.0	2.0	1069.0	22.27	26.34	21.97	27.16
1025.0	4.0	1.0	849.0	22.07	26.65	21.86	27.45
1011.0	95.0	1.0	624.0	21.99	26.98	21.70	27.85
1001.0	303.0	2.0	151.0	21.68	27.62	21.30	28.25
1048.0	502.0	4.0	-336.0	21.25	28.21	20.91	28.91
1523.0	-281.0	6.0	1916.0	22.70	25.11	23.23	25.98
1517.0	-77.0	6.0	1534.0	22.90	25.70	22.29	26.54
1519.0	19.0	5.0	1320.0	22.39	26.04	22.13	26.85
1522.0	117.0	5.0	1095.0	22.23	26.36	22.01	27.18
1515.0	318.0	4.0	623.0	21.91	27.07	21.66	27.82
1515.0	518.0	4.0	131.0	21.56	27.70	21.30	28.42
1994.0	-77.0	9.0	1963.0	22.51	25.13	22.45	25.98
1966.0	13.0	9.0	1791.0	22.62	25.36	22.41	26.22
2015.0	113.0	9.0	1578.0	22.54	25.71	22.33	26.56
2015.0	310.0	6.0	1095.0	22.15	26.48	21.86	27.25
2010.0	518.0	7.0	624.0	21.88	27.12	21.62	27.87
2518.0	9.0	13.0	2226.0	22.88	24.81	22.60	25.66
2518.0	111.0	12.0	2045.0	22.74	25.11	22.49	25.96
2500.0	314.0	11.0	1596.0	22.43	25.82	22.21	26.64
2515.0	520.0	10.0	1137.0	22.23	26.48	22.01	27.27
67.0	-3.0	-2.0	8.0	21.64	27.66	21.26	28.41

Table 5a - Comparison of Measured Undercarriage Vertical Loads with Estimated Vertical Loads.

Bending Moment (lb.in)	Axial Load (lb)	Applied Vertical Load (lb)	Est'd Vertical Load (lb)	Res.	Res. %
1153.700	-327.000	53.500	53.990	-0.490	-0.917
702.700	-199.100	30.000	30.317	-0.317	-1.056
269.000	-46.700	33.500	34.079	-0.579	-1.729
58.100	33.900	42.500	42.455	0.045	0.106
-147.600	126.200	63.500	62.637	0.863	1.360
-700.100	252.500	25.000	21.421	3.579	14.317
1568.600	-173.400	287.500	286.024	1.476	0.513
1101.600	-63.200	245.000	244.737	0.263	0.107
686.400	96.300	257.000	258.948	-1.948	-0.758
457.400	167.600	253.000	255.084	-2.084	-0.824
241.100	243.300	258.000	258.952	-0.952	-0.369
-296.800	413.700	259.000	257.904	1.096	0.423
-805.000	564.700	258.000	253.247	4.753	1.842
2010.100	-46.500	506.000	501.580	4.420	0.873
1531.400	101.100	485.000	486.121	-1.121	-0.231
1161.000	259.100	508.500	510.806	-2.306	-0.453
933.700	339.500	512.500	514.593	-2.093	-0.408
712.700	403.500	505.500	508.067	-2.567	-0.508
206.800	557.100	500.500	501.745	-1.245	-0.249
-252.200	722.700	524.000	521.084	2.916	0.556
2028.500	287.900	761.500	758.036	3.464	0.455
1612.400	439.800	758.500	766.157	-7.657	-1.010
1375.900	512.900	759.500	762.128	-2.628	-0.346
1152.700	587.800	761.000	763.785	-2.785	-0.366
665.700	737.200	757.500	759.516	-2.016	-0.266
165.300	888.000	757.500	757.116	0.384	0.051
2031.500	596.400	997.000	990.825	6.175	0.619
1825.500	655.100	983.000	983.647	-0.647	-0.066
1650.300	746.600	1007.500	1009.769	-2.269	-0.225
1175.600	895.200	1007.500	1007.945	-0.445	-0.044
661.800	1050.500	1005.000	1005.963	-0.963	-0.096
2381.900	833.300	1259.000	1254.572	4.428	0.352
2153.500	910.200	1259.000	1256.362	2.638	0.210
1660.800	1057.400	1250.000	1249.265	0.735	0.059
1182.100	1217.800	1257.500	1259.664	-2.164	-0.172
67.300	19.700	33.500	33.458	0.042	0.124

Table 5b - Comparison of Measured Undercarriage Side Loads with Estimated Side Loads.

Bending Moment (lb.in)	Axial Load (lb)	Applied Side Load (lb)	Est'd Side Load (lb)	Res.	Res. %
1153.700	-327.000	-480.000	-480.439	0.439	-0.092
702.700	-199.100	-290.000	-290.290	0.290	-0.100
269.000	-46.700	-91.000	-91.542	0.542	-0.596
58.100	33.900	8.000	8.012	-0.012	-0.148
-147.600	126.200	112.000	112.800	-0.800	-0.714
-700.100	252.500	313.000	316.084	-3.084	-0.985
1568.600	-173.400	-480.000	-478.749	-1.251	0.261
1101.600	-63.200	-297.000	-296.736	-0.264	0.089
686.400	96.300	-96.000	-97.668	1.668	-1.738
457.400	167.600	2.000	0.209	1.791	89.571
241.100	243.300	98.000	97.189	0.811	0.828
-296.800	413.700	323.000	323.976	-0.976	-0.302
-805.000	564.700	524.000	528.183	-4.183	-0.798
2010.100	-46.500	-502.000	-498.111	-3.889	0.775
1531.400	101.100	-288.000	-288.995	0.995	-0.346
1161.000	259.100	-99.000	-101.031	2.031	-2.051
933.700	339.500	4.000	2.251	1.749	43.734
712.700	403.500	95.000	92.766	2.234	2.351
206.800	557.100	303.000	301.873	1.127	0.372
-252.200	722.700	502.000	504.553	-2.553	-0.509
2028.500	287.900	-281.000	-277.993	-3.007	1.070
1612.400	439.800	-77.000	-83.701	6.701	-8.703
1375.900	512.900	19.000	16.705	2.295	12.080
1152.700	587.800	117.000	114.548	2.452	2.096
665.700	737.200	318.000	316.301	1.699	0.534
165.300	888.000	518.000	518.279	-0.279	-0.054
2031.500	596.400	-77.000	-71.614	-5.386	6.995
1825.500	655.100	13.000	12.444	0.556	4.281
1650.300	746.600	113.000	111.003	1.997	1.767
1175.600	895.200	310.000	309.568	0.432	0.139
661.800	1050.500	518.000	517.147	0.853	0.165
2381.900	833.300	9.000	12.916	-3.916	-43.513
2153.500	910.200	111.000	113.295	-2.295	-2.068
1660.800	1057.400	314.000	314.592	-0.592	-0.189
1182.100	1217.800	520.000	518.158	1.842	0.354
67.300	19.700	-3.000	-2.983	-0.017	0.580

Table 6 - History of Load Spectra

Designation	Spectrum	Details	Period
PRELIM	100	Preliminary flight spectrum	2-6-83 to 1-7-83
PENULT	200	Rare loads added	4-8-83 to 4-8-83
PENULT	210	Gust loads corrected	4-8-83 to 5-9-83
PEN2	220	Undercarriage corrected	10-10-83 to 19-6-84
PEN5	230	Gust loads removed 1g added to peaks (to 6g) 0.5g subtracted from troughs (to -2.5g)	25-6-84 to 31-8-84

Table 7 - CT4 Fatigue test Jackloads (lb)
For Special Flight containing Rare Loads
(SPECTRUM 220)

Modulus	Wing	Undercarriage Vert.	Undercarriage Side	Tailplane	Fin	U/C Drag	Turning Point
1	60.0	44.0	0.0	0.0	0.0	22.0	1
1	60.0	2296.0	169.0	0.0	0.0	22.0	2
1	60.0	1368.0	-108.0	0.0	0.0	377.0	3
1	60.0	2240.0	109.0	0.0	0.0	22.0	4
1	635.3	44.0	0.0	-33.4	-61.4	22.0	5
1	1434.1	44.0	0.0	0.7	-2.8	22.0	6
1	669.3	44.0	0.0	-14.3	-6.8	22.0	7
1	1364.5	44.0	0.0	3.1	24.5	22.0	8
1	679.4	44.0	0.0	-34.6	0.0	22.0	9
1	1455.7	44.0	0.0	-16.3	19.0	22.0	10
1	667.7	44.0	0.0	-33.3	0.7	22.0	11
1	1527.3	44.0	0.0	-11.2	12.1	22.0	12
1	613.4	44.0	0.0	-7.6	4.0	22.0	13
144	2672.6	44.0	0.0	-11.2	-3.0	22.0	14
144	613.4	44.0	0.0	-7.6	4.0	22.0	15
1	1148.9	44.0	0.0	-56.9	-5.7	22.0	16
2	687.9	44.0	0.0	-38.5	-4.8	22.0	17
2	2439.0	44.0	0.0	20.4	6.4	22.0	18
1	308.8	44.0	0.0	18.1	-8.5	22.0	19
1	1002.4	44.0	0.0	1.4	4.1	22.0	20
1	521.7	44.0	0.0	-32.8	12.4	22.0	21
1	1197.9	44.0	0.0	-131.8	46.8	22.0	22
1	665.6	44.0	0.0	-104.5	-5.4	22.0	23
1	2160.7	44.0	0.0	-32.4	-3.4	22.0	24
24	-1670.0	44.0	0.0	-70.0	-4.0	22.0	25
24	714.6	44.0	0.0	-104.5	-5.4	22.0	26
16	-63.7	44.0	0.0	-13.3	9.5	22.0	27
16	2242.4	44.0	0.0	-6.2	38.0	22.0	28
24	-543.4	44.0	0.0	-59.7	11.0	22.0	29
24	1863.5	44.0	0.0	-100.0	38.6	22.0	30
144	521.7	44.0	0.0	-32.8	12.4	22.0	31
144	4008.0	44.0	0.0	-60.0	25.0	22.0	32
1	516.8	44.0	0.0	-228.7	90.4	22.0	33
6	2779.7	44.0	0.0	-2.6	36.6	22.0	34
6	546.2	44.0	0.0	-58.3	3.5	22.0	35
1	1396.0	44.0	0.0	-105.8	9.5	22.0	36
18	525.2	44.0	0.0	-129.8	11.0	22.0	37
18	3708.6	44.0	0.0	-11.2	-3.0	22.0	38
1	103.6	44.0	0.0	-21.8	43.7	22.0	39
18	1433.1	44.0	0.0	26.5	-31.8	22.0	40
18	-1418.6	44.0	0.0	-44.8	-16.5	22.0	41
4	3427.0	44.0	0.0	-34.7	24.5	22.0	42
4	664.5	44.0	0.0	-43.1	14.6	22.0	43
1	1060.5	44.0	0.0	-40.0	4.7	22.0	44
1	143.5	44.0	0.0	-90.2	22.1	22.0	45

Table 7 (continued) - CT4 Fatigue test Jackloads (lb)
For Special Flight containing Rare Loads
(SPECTRUM 220)

Modulus	Wing	Undercarriage Vert.	Undercarriage Side	Tailplane	Fin	U/C Drag	Turning Point
1	1944.3	44.0	0.0	-103.8	27.3	22.0	46
1	565.7	44.0	0.0	-81.4	32.2	22.0	47
1	1151.3	44.0	0.0	-130.2	3.5	22.0	48
9	709.7	44.0	0.0	-117.8	18.1	22.0	49
9	2977.0	44.0	0.0	6.7	6.4	22.0	50
1	30.1	44.0	0.0	-50.2	-2.2	22.0	51
1	2180.9	44.0	0.0	-21.1	-30.1	22.0	52
1	661.2	44.0	0.0	-27.7	-5.7	22.0	53
1	1262.5	44.0	0.0	-8.7	17.0	22.0	54
144	2004.0	44.0	0.0	-27.7	-5.7	22.0	55
144	661.2	44.0	0.0	-27.7	-5.7	22.0	56
1	699.1	44.0	0.0	-14.7	2.1	22.0	57
1	1567.0	44.0	0.0	-200.5	-7.0	22.0	58
1	-311.0	44.0	0.0	-112.9	114.3	22.0	59
1	959.8	44.0	0.0	-36.7	5.8	22.0	60
1	552.5	44.0	0.0	-49.7	-0.2	22.0	61
1	963.9	44.0	0.0	-25.3	-18.3	22.0	62
1	564.4	44.0	0.0	-65.7	11.9	22.0	63
1	1548.8	44.0	0.0	-64.0	2.3	22.0	64
1	665.9	44.0	0.0	-93.2	37.6	22.0	65
6	60.0	3786.0	102.0	0.0	0.0	22.0	66
6	60.0	44.0	-167.0	0.0	0.0	22.0	67
6	60.0	1902.0	-167.0	0.0	0.0	22.0	68
6	60.0	44.0	-182.0	0.0	0.0	22.0	69
6	60.0	1312.0	-40.0	0.0	0.0	22.0	70
6	60.0	44.0	-115.0	0.0	0.0	22.0	71
6	60.0	2240.0	109.0	0.0	0.0	22.0	72
6	60.0	44.0	0.0	0.0	0.0	22.0	73
144	60.0	44.0	0.0	0.0	0.0	22.0	74
144	60.0	2296.0	169.0	0.0	0.0	22.0	75
144	60.0	1368.0	-108.0	0.0	0.0	377.0	76
144	60.0	2240.0	109.0	0.0	0.0	22.0	77
144	60.0	44.0	0.0	0.0	0.0	22.0	78
144	60.0	4192.0	291.0	0.0	0.0	22.0	79
144	60.0	44.0	-195.0	0.0	0.0	22.0	80
144	60.0	3332.0	135.0	0.0	0.0	22.0	81
144	60.0	44.0	-58.0	0.0	0.0	22.0	82
144	60.0	2826.0	95.0	0.0	0.0	22.0	83
144	60.0	44.0	-28.0	0.0	0.0	22.0	84
144	60.0	2240.0	109.0	0.0	0.0	22.0	85
144	60.0	44.0	0.0	0.0	0.0	22.0	86
1	352.0	1360.0	217.0	0.0	0.0	22.0	87
1	352.0	44.0	-140.0	0.0	0.0	22.0	88
1	352.0	2240.0	109.0	0.0	0.0	22.0	89
1	60.0	44.0	0.0	0.0	0.0	22.0	90

TABLE 8 - COMPARISON OF FATIGUE TEST AND FLIGHT TRIALS EXCEEDANCE LEVELS AND HOURS

PROGRAMS	EXCEEDANCE LEVELS (g) -2.5	-2.0	-1.5	-1.0	-0.5	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5	6.0	REFERENCE
1-36	0	-	252	-	864	-	-	9972	-	2736	-	288	0	0	0	PRELIM
37-127	4	10	192	1102	3836	53839	36583	26319	17579	8019	2786	939	29	6	0	PENULT
128-648	21	49	1091	6301	21952	281157	206971	150675	100638	45896	15939	5372	162	32	4	PEN2
1-648	25	-	1535	-	26752	-	-	186966	-	56651	-	6599	191	38	4	
Eq. Pt Cook Hours	18751		28616		21834			25852		29250		27828			19314	
649-720	7	151	871	3034	5486	55892	55820	43793	33497	24709	15634	6630	2346	22	4	PEN5
721-798	9	165	936	3253	5887	59939	59862	46957	35918	26492	16764	7115	2522	26	6	PEN5
Eq. Pt Cook Hours	11885		33688		9282			12548		26437		57963			48285	
Total Test Exceedances	41		3342		38125			277716		107852		20344			14	
Total Equ. Pt Cook Hours	30456		62304		31116			38400		55687		85791			67599	

Table 9 - Comparison of Flight Trials Strains with Fatigue Test Strains.

(Microstrain)

	5.13g		0.15g		-2.1g	
	9BE	10BE	9BE	10BE	9BE	10BE
Flt. Trials	-1107	-1076	-5	-3	502	484
Prog. 37	-1181	-1197	-28	-46	541	496
Prog. 72	-1185	-1190	-36	-41	521	514
Prog.144	-1179	-1187	-37	-46	523	509
Prog.216	-1210	-1211	-36	-40	528	517
Prog.288	-1213	-1210	-36	-41	536	519
Prog.360	-1215	-1216	-39	-39	544	533
Prog.432	-1216	-1219	-40	-39	548	534
Prog.504	-1233	-1224	-36	-39	572	541
Prog.576	?	?	-35	-29	572	552

APPENDIX

A1. Wing Loads

Flight Loads are separated into bending and torsion components. The bending moment and torsion distributions are obtained from theoretical and empirical methods used in the Airtrainer Design Report CT4-4 (Ref. 5). With these distributions, the reference condition was the high angle of attack case scaled to 1g. Nine wing strain gauges were selected to evaluate loads from flight trials strain histories.

Using gauge sensitivities from ground calibrations (Ref.6) with load distributions as described above, a least squares model was fitted to establish root bending moments. These values were divided by a 1g reference bending moment to produce calculated normal acceleration.

All loads were symmetrical, based on the average strain sensitivity for a typical training program simulated in the flight trials. A single load distribution was used to reproduce the average strain distribution measured during the test flights. This was adjusted to an AUW of 2500 lb (minus half fuel -- 162 lb).

Torque was achieved by offsetting the wing jack load path from the flexural centre of the wing, resulting in the torque being a constant proportion of the bending moment.

The 1g reference bending moment is 44415 lb.in. (5018 Nm), the wing root is located at station 21 inches (533 mm), and the line of action of the wing jack is at station 87.49 inches (2222 mm).

Therefore the required jackload :-

$$Jw = 444158/(87.49-21) = 668 \text{ lb/g}$$

$$= 2970 \text{ N/g}$$

A2. Empennage Loads

A2.1 Horizontal Tailplane

Horizontal tailplane loads were calculated using a tangent construction. Bending moments were evaluated at the two strain gauge positions of the starboard tailplane using calibration information from reference 6. Zero moment was assumed at the tip. A quadratic equation was then fitted to the three values and extrapolated to the root. All this could be represented as a linear function of the two measured bending moments. A quadratic equation was then fitted to the three values and extrapolated to the root.

The line of action of tailplane jack is at station 36 inches (914 mm) with the root at station 3 inches (76.2 mm). Therefore the required tailplane jackload per side :-

$$Jw = BMrt/33 \quad \text{lb.}$$

A2.2 Fin

The fin jackload is applied to the fin at station 26.41 inches (670 mm) to reproduce the required root bending moment at station 8 inches (203 mm). Root bending moments Ms and Mp for starboard and port side of the fin are calculated using the calibration data from reference 6. These are then averaged and divided by the moment arm.

$$\text{i.e.}\quad Jf = (Ms+Mp)/2(26.41-8) \quad \text{lb.}$$

A3. Undercarriage Loads

To enable the correct loads to the undercarriage to be calculated from flight trials strain measurements, a calibration was carried out during August 1983 and the relationships of bending moments and axial loads to strain was evaluated.

A multilinear model was established to calculate the vertical and side jack loads from the bending moments and axial loads. It took the form:

$$V = 0.2671Bm + 0.8079P - 2.7472\ \exp(-5)Bm.P - 0.3987$$

$$S = -0.2325Bm + 0.6226P + 2.3932\ \exp(-5)Bm.P + 0.3667$$

where V is vertical jackload, positive up
S is side jackload, positive inboard
Bm is normal bending moment
P is axial load

The calculation of drag load is shown in reference 4, and is reproduced here:

$$X = -5.77381\ \exp(-6)\ V^2 - 0.36607V + 0.138095$$

$$Jd = (Sd - X)/0.305003$$

where X is a dummy variable
Jd is the drag jackload
Sd is the strain due to transverse bending of the undercarriage leg.

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16. Abstract

This document presents an outline of the derivation of the test load sequences applied to the CT4 full scale fatigue test.

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